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THE EXTRA-VASCULAR CIRCULATION.

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There is, perhaps, no question in physiology of so much practical importance to the medical man as the one which relates to the source of the extra-vascular circulation and the phenomena connected therewith.

As a basis for what I may have to offer on this subject, the following propositions have been formulated, namely: *The conversion of pabulum into bioplasm is the primary and chief source or cause of the extra-vascular circulation, as also that of the evolution of animal heat.*

Second: *The conversion of bioplasm into solid or nearly solid formed material contributes in a lesser but no less important degree to the same dual results.*

Third: *The nutritive demand will be found to harmonize absolutely with the relative size, numbers and nutritive activity of the germinal matter of any cell, tissue, structure or organ of the body.*

Fourth: *Any agent or class of agents that tends to destroy or injuriously effect the substance of bioplasm or to thicken the serum of the blood or the walls of the vessels, and especially of the cells, is essentially detrimental to the nutritive interests of the economy, as also that of the motor, secretory and excretory functions.*

The human embryo essentially consists of an aggregated mass of bioplasm, living corpuscles, each of which is destined to grow, and divide, and redivide, and thus to produce innumerable particles like themselves. This process of growth and multiplication will continue just so long as they are freely supplied with proper pabulum, but there comes a time when in consequence of the physiological arrangement and anatomical conformation of the maternal structures the increase of pabulum cannot keep pace with that of the living

elements to be nourished, and hence they undergo formative change in part, and thus we have developed the various tissues and organs as displayed in the mechanism of man. The quantity of pabulum is not actually reduced, but the living matter has simply ceased to multiply because the balance between the supply and demand has been obtained, and any further increase in the volume of living matter, in the absence of the necessary elements at the expense of which it may increase, is an utter impossibility.

The bioplasm continues to grow, however, but under increased restricted nutritive activity proportionate to the thickness and density of the individual condensed formative products. And this very change leads to a relative disproportion in an opposite direction from that just stated, so that whatever naked living matter may continue to exist will be freely supplied with pabulum, and thus provision is made whereby growth and multiplication and formative change or organization may go on and on until man's perfect estate is reached.

Cornil and Ranvier say: "At its origin, every cell is composed solely of a mass of protoplasm surrounding a nucleus. * * * Even the nucleus is not now considered by some skilled histologists to be essential to a cell. For them the simplest cell consists of a mass of living protoplasm."

How marvelous are the workings of this mysterious force called "vital force"!

From one little corpuscle two are made, from these four or more result, and thus the process of growth and multiplication goes on and on until at last a type of the most perfect organism in the scale of creation is developed—consisting of innumerable corpuscles—living cells corpusculated without a liver or spleen, vitalized without a brain or other nervous apparatus, shaped without moulds, and formed without hands; yea, and propelled without propellers other than their own inherent vital energy.

Had it not been for the revelations of the microscope the very existence of this wonderful matter could not have been known, its miraculous and varied phenomena could not have been recorded on the tablets of the brain; its changes of form, its growth and multiplication, its formative powers and transformative capacities, all

would have been forever shrouded in the unfathomable mystery of God's creative wisdom. But thanks to the ingenuity of man we know that these statements are true, we know that any one who is sufficiently interested in the prosecution of microscopical research to exercise care, patience and diligence may witness all the wonderful manifestations of vital energy, the marvelous display of formative power, if he will. We know that bioplasm is the only matter in the world that can convert other things into its own substance and thereby grow and multiply; we know that it is the only matter that can produce new tissue, and renew that which is old, and restore that which is lost. We know that bioplasm must have pre-existed, then, before an organism, organ, tissue or cell could have been produced, and that, therefore, life does not come from organization, but all organic structure is the result of change taking place in bioplasm. All cells, then, whatsoever their size, shape, composition, function or other peculiar characteristics, have the same genetic origin, the same wonderful builder, a builder that has neither organs, tissues or structures, and yet it is the progenitor of all organs, tissues, and all organic structures.

Again, every cell has the same histological conformation, namely, bioplasm and formed material. The bioplasm existed first, and the formed material was the result of condensation having taken place on the surface of the former.

The cell has been aptly defined as "The morphological unit of organization, the physiological source of specialized function." Every functional action, then, is but the expression of life-force made manifest through bioplasm primarily, but remotely it may be, through the lifeless formed material which constitutes its protective covering.* Now naked living matter may grow at the expense of substances in almost any state of consistency providing they are brought into immediate contact with such substance, but bioplasm that is enveloped by a cell-wall must of necessity be supplied with fluid pabulum, or in other words, with pabulum in such a minute state of division as to permit its passage through the substance of

* See Paper entitled "Muscular Contractility," Proceedings American Society of Microscopists, 1881.

the cell-walls so as to gain access to the living germ within, and which alone is the theater of nutritive activity.

The same is equally true of bioplasm in every condition of external surroundings if any kind of membrane or other solid substance intervene between it and its nutrient supply.

This is the condition of most, if not all, of the living elements of the entire economy of man. And, hence, we may define pabulum as a fluid substance, and bioplasm is shown to be a transparent, colorless, *entirely structureless*, semi-fluid substance, and formed material is, as a rule, of solid or nearly solid consistency.

In the conversion of a fluid into a semi-fluid a reduction in volume takes place. The same thing occurs on converting a semi-fluid into a solid substance. Now the inevitable result of the conversion of fluid pabulum into semi-fluid bioplasm, and again, of the latter into solid formed material, would be the formation of a vacuum did not more fluid rush in to take the place of that which is thus lost in volume. And since it is the life-force, operating in and through bioplasm, that effects both these changes, either directly or indirectly, in other words, since it is within the cell that these changes are effected, it follows as a necessary consequence that the pabulum will thus be caused to traverse both the vascular and the cell-walls and reach the living nucleus or germ within. The reduction in volume is effected at the expense of an atmosphere of heat, and hence the temperature will, *cetera paribus*, be found to harmonize closely with the degree of activity of the nutritive changes. It must not be forgotten, however, that certain nutrient elements, such as the fats for instance, have a greater inherent capacity for heat than others; that a certain indefinite quantity of caloric is economized in effecting disintegrative changes, and again, that under certain circumstances an indefinite quantity may be retained in excess of the normal, and thus somewhat vitiate the result as above stated.

Those who have espoused the physical theory of life have endeavored to explain the phenomena of the extra-vascular circulation upon chemical principles, but there are too many facts which controvert such a hypothesis to admit of its acceptance, and there are some that fully demonstrate the utter falsity of the proposition. When chemical union takes place the elements thus combined lose

their individual identity, and gain new characteristics as a corporate body, while in the process of nutrition the pabulum is changed, the bioplasm remaining precisely the same in both its physical properties and chemical composition. Moreover, bioplasm is not, neither indeed can it be, a chemical product, as is conclusively proven by all the facts of biology and histology. Again, this is not all there is of the extra-vascular circulation, for we find that the tissues of man are the subjects of disintegration as well as integration,—the subjects of waste as well as repair,—and hence that certain effete elements must be got rid of through the operation of life-force. And it is a remarkable fact, the clinical importance of which cannot be overestimated, that those tissues and organs which undergo most rapid waste and repair,—which perform a secretory or an excretory function,—are the very ones that communicate with, and discharge their waste products into, the outside world, if you will allow me the expression. These are the tissues which are most richly supplied with blood-vessels, and where bioplasm is most active in nutritive change, and is greatest in relative quantity.

The waste products of those tissues and structures which do not communicate with the outside world through the medium of excretory ducts, such as the muscles, nervous tissue, bone, etc., is exceedingly slight in quantity, comparatively speaking, and is simply designed for the purpose of maintaining the organism in a state of purity, vigor, and strength.

Now it is not claimed by any one, I believe, that bile or gastric juice, for instance, already exists pre-formed in the blood, and certainly no one who is acquainted with the nature of bioplasm and its condensed product, formed material, will pretend to say that either of these two elements constitute the substance in question.

Bioplasm does not convert pabulum into bile or gastric juice, but into its own living substance. Formed material is not identical with, but may be closely related to the disintegrated product. Disintegration is not effected through the direct agency of living matter, but as the result of physical influences. When bioplasm disintegrates formed material it converts it back into bioplasm. Bile, gastric juice, in fact all of the so-called secretions, together with the worn-out and effete tissue-detritus are the result of physical

disintegration of the outermost substance of the cells, and this process is just as essential to the well-being of the organism as is bioplastic growth and formative change, and heat is pre-eminently the most active agent in effecting this result—another fact of considerable clinical importance, but unfortunately one that is not made use of sufficiently often.

The bioplasm of the hepatic cells does not appropriate precisely the same kind of pabulum that goes to nourish the nervous system, and what constitutes the proper and indispensable food for the renal bioplasm cannot be assimilated by either of the former elements. The living matter of the articular cartilages are wholly dependent upon the synovial fluid for their nutrient supply, and strange as it may, at first thought, seem, the white blood-corpuscles as also the vascular bioplasts which exist in such vast numbers in the walls of the capillaries, and especially in those of the venous radicles, draw their nutrient supply, not from the blood plasma, but from the regressive products of the muscular, bone, nervous, and other such tissues as already spoken of.

In harmony with these statements we should find an increase in the relative number of white blood-corpuscles, and such other bioplasts as are allied to these in nutritive function, in all cases in which there is increased waste of those tissues which do not discharge their regressive elements into the outside world. And the same thing should prove equally true in cases in which an increased eliminative burden is imposed upon them, accepting this opinion.

Now, it is well known that in the case of frogs and other hibernating animals, in the spring of the year, when the muscles have become fatty-degenerated and greatly atrophied, the white blood-corpuscles are exceedingly numerous, notwithstanding that they have constantly undergone regressive change, and thus yielded up a portion of their substance as pabulum for the nervous and other tissues necessary to the continuance of coördinate vitality. The same thing is true in the emaciation of fevers in pregnancy,—in which case there is an increased eliminative burden imposed upon these bioplasts.

For farther proof of the correctness of this opinion I appeal to the results of chemical experience. In accordance with the above

statements we should find on careful investigation that the nutritive activity of any given part will be determined by the facility of access of proper pabulum on the one hand, and the relative quantity of bioplasm to be nourished on the other.

It is a universal law governing the nutritive changes of living matter that when the access of pabulum is unrestricted they grow and multiply rapidly; if the nutritive supply be materially restricted they do not multiply, but while they grow at the expense of the former they just as constantly lose by formative change in their outer part, and this latter is prevented from accumulating injuriously by disintegration and final elimination. If, however, the nutrient supply be wholly cut off from any given part, the living matter, as also the formed material, undergoes fatty decomposition or other regressive metamorphosis. Vital force never determines a formative change then, until the volume of bioplasm has so increased as to lead to a relative disproportion between the nutrient supply and the elements to be nourished. This fact is beautifully exemplified in cases in which an initial lesion of cells has occurred, as for instance, a fatty granular decomposition of a limited number of bone corpuscles, or in which an injury has been sustained whereby a loss of vitality and of structural integrity of a circumscribed part of the economy is superinduced.

Now it is quite evident that such part is no longer competent to be nourished; no longer capable of performing its functions; that it is in fact a dead and disturbing—although perfectly passive—element, and ought to be got rid of and new structure developed in its stead.

The bioplasm of the contiguous elements takes on increased nutritive activity, not in consequence of a stimulus or “irritant applied to it,” but simply as the result of an increased access of pabulum to the living matter of such parts. The number and capacity of the blood-vessels distributed to any given part is proportionate to the physiological demands of such part, and while it must be admitted that these remain the same in numbers, and are but slightly increased in caliber, we find nevertheless, that there is a more abundant supply of pabulum for the elements just spoken of, for the bioplasm of the injured tissues has lost its vitality, and consequently

has ceased to exert an attractive influence, so to speak, and hence the nutrient matter which was being distributed to it is now appropriated by the living matter contiguous thereto.

The injured structures remaining, soon experience regressive change,—the product of which is in part assimilated by the *now* naked living matter, in part is eliminated through the agency of the blood, vascular and other eliminating bioplasts,—so that finally all the dead tissue, together with a portion of the contiguous structures is wholly replaced by embryonal matter.

The circumferential bioplasts draw their nutrient supply from that which was being distributed to them by virtue of their anatomical position, from that which formerly passed by them on its way to the bioplasm of the diseased part, and from the metamorphosed products of this structure itself.

But all these sources of supply would not be sufficient to compensate for the increase of germinal elements over that normally existing in the parts thus involved, and which increase is so absolutely essential to the repair of lesion.

It will not do to say that the nutrient fluid is caused to transude through the vascular walls as the result of a *vis a tergo*,—by virtue of the cardiac impulse,—for such an hypothesis would lead to a dropsical effusion in the first place, could not effect its passage into the germ of the cell, and would completely fail to explain the reverse extra-vascular current.

Moreover, the cornea, the developmental, and the articular cartilages, for instance, are entirely destitute of blood vessels, and the last mentioned are dependent upon the synovia for their pabulum.

Upon the whole, then, we are forced to adopt the conclusion that the constantly augmenting volume of bioplasm exerts a just as constantly increasing attractive force, thus leading to a more rapid transudation of fluid pabulum through the walls of the vessels, a more rapid circulation through these latter as a secondary consequence, until finally the limit or capacity has been reached. The bioplasm is thus enabled to increase so as to eventually equal, or even exceed in many instances, the volume of the original structure, when by virtue of the mechanical pressure which they exert upon the *now embryonal blood-vessels* and their relative proportionate

increase over the available pabulum, a formative change is determined and thus the reparative process is completed.

I can conceive of no greater display of creative wisdom than is made manifest in the physiological arrangement and anatomical conformation whereby the nutrition, growth, and multiplication, formative change, and functional action of embryonal matter—*bioplasm*—is determined and controlled. Nor can I conceive of anything more absurdly erroneous, or more dangerously pernicious than to thwart *vis vite* in the accomplishing of these processes.

For instance, any agent that tends to destroy or diminish the quantity of white blood-corpuscles, and other eliminative bioplasts, otherwise than by correcting the conditions upon which their increased nutrient supply was and is dependent, will be to leave a mass of effete matter in the substance of the tissues to still farther obstruct them in the performance of their specific functions. Any reduction in the size of the muscular bioplasts will necessarily diminish the force of the muscular contraction in a twofold manner: namely, the loss of bioplasm is a loss of just so much force or functional energy upon which the contractions depend,* and secondly, by increasing the resistance to the spherical conformation of the bioplasts by virtue of the greater thickness and density of the cell-walls themselves. Again, the nutritive interchange between the blood-mass and the bioplasts will be very materially interfered with, first, as the legitimate result of the diminished demand, and second, even this demand cannot be complied with because of the increased thickness and (in the case of alcohol) density of the cell-walls, the walls of the vessels, and indeed the serum of the blood.

The same statement holds good in the case of the secreting, excreting, and all other cells, so far as their nutrition, growth and functional activity are concerned.

Again, every such influence must necessarily have a more or less permanently depressing effect upon the calorific function of the body, owing to the degree and persistency of the state thus induced.

* See paper on Muscular Contractility, referred to already.